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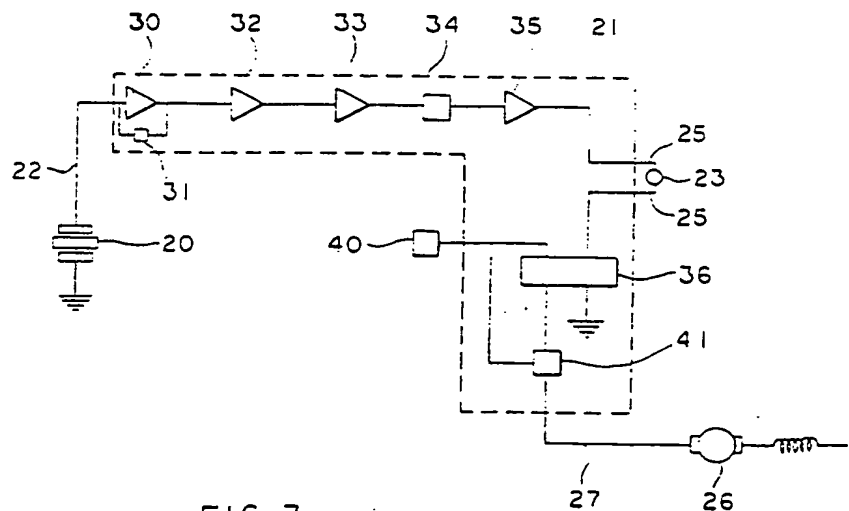
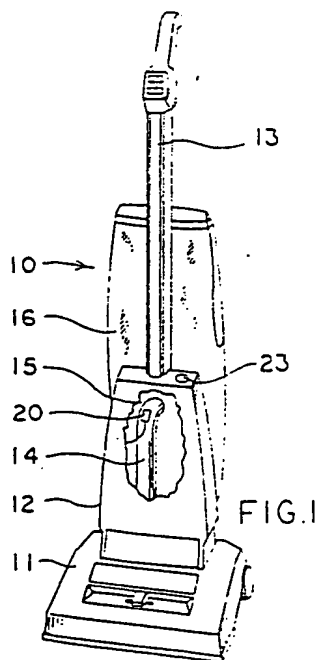
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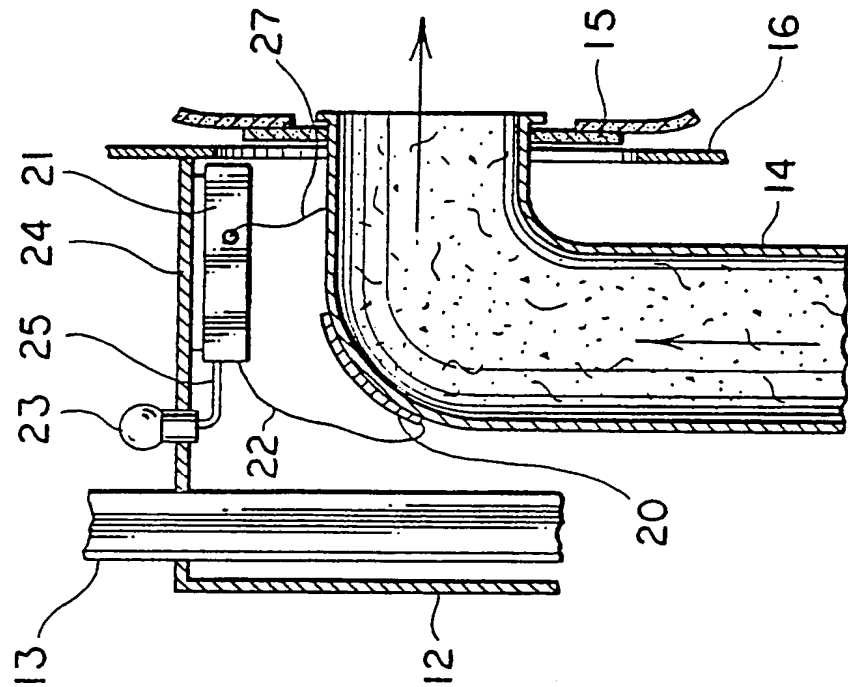
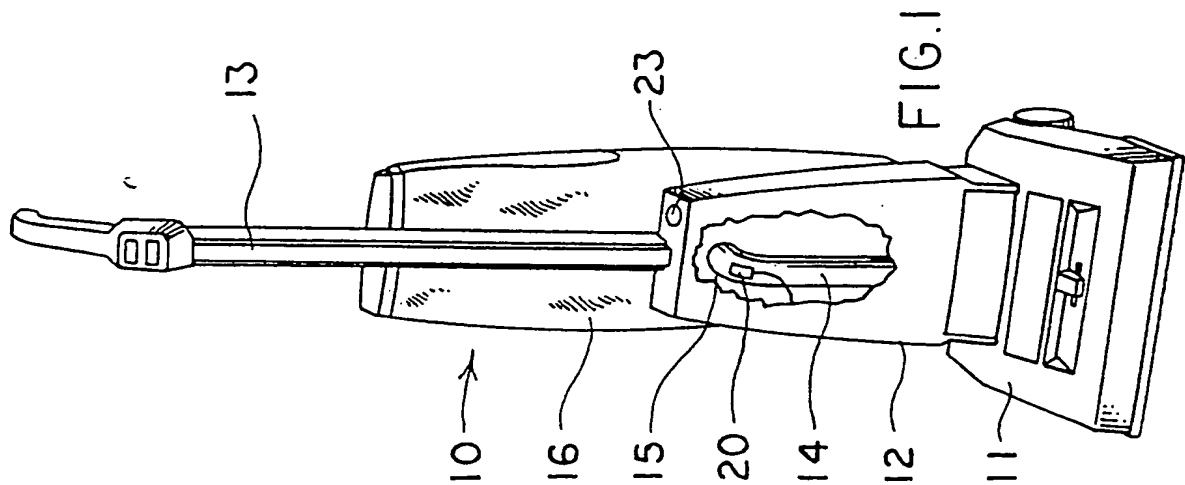
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(54) Vacuum cleaner with dirt sensor

(57) A vacuum cleaner 10 is provided with a sensor 20 responsive to interaction between suction duct 14 and the dirt flowing therethrough to produce an electrical signal representative of the dirt within the airflow in the duct. The sensor, which may be secured to the exterior surface of the duct, may detect acoustical and/or mechanical vibrations or electrostatic charge. The electrical signal may be fed to a control module 21 for controlling the operation of motor 26 e.g. its speed and activating indicator light 23. The cleaner may be of the upright or canister type. The sensor may be located at other positions along the dirt flowpath through the cleaner.



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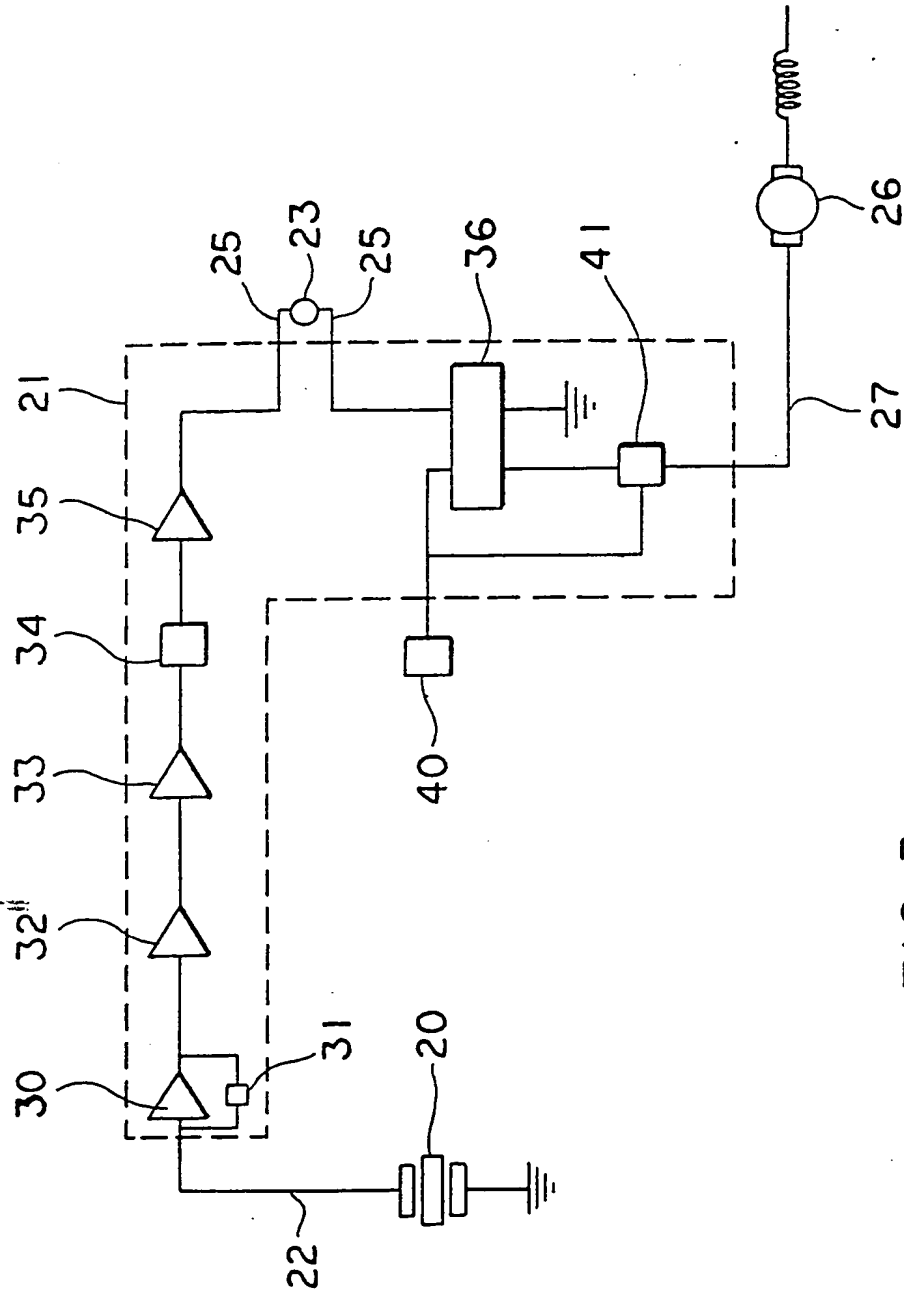


FIG. 3

1                   Vacuum Cleaners Having Dirt Sensors

2  
3           The present invention relates generally to vacuum  
4 cleaners and more particularly, to a vacuum cleaner  
5 having a sensor for detecting the presence of dirt in  
6 an airflow passageway therein.

7           Vacuum cleaners are widely used to clean dirt and  
8 debris from carpets, fabrics and various other  
9 materials and surfaces. A vacuum cleaner generates a  
10 flow of air through a passageway one end of which  
11 defines an inlet and is presented to the vicinity of  
12 the dirt and debris. The airflow generated by the  
13 vacuum cleaner carries the dirt and debris into the  
14 passageway inlet subsequently to be trapped or  
15 collected in a suitable container or bag for subsequent  
16 disposal.

17           A problem associated with using a vacuum cleaner  
18 is determining when the area being cleaned is  
19 substantially free of dirt and debris. Generally, on  
20 bare surfaces, the operator can visually inspect the  
21 area and determine whether further cleaning is  
22 necessary. For carpeting, fabrics and other surfaces,  
23 however, the dirt may not easily be visible to the  
24 operator; instead it may be trapped within the carpet  
25 fibres or the like. The operator, then, can merely  
26 operate the vacuum cleaner over an area for a period of  
27 time believed to be sufficient to remove the dirt and  
28 debris. Depending on the particular situation,  
29 however, the time period may be inadequate, resulting  
30 in dirt and debris being left in the carpet or the  
31 like. Alternatively, the time period may be unduly  
32 protracted, which results in an inefficient use of time  
33 and energy to clean a particular area. This may also

1 result in increased wear of the carpet itself.

2 In addition to the foregoing, it may be desirable  
3 to regulate the operation of the vacuum cleaner in  
4 response to the presence of dirt and debris. For  
5 mildly soiled areas, the cleaner may be operated at a  
6 reduced power setting to conserve energy and to lessen  
7 wear of the cleaner components as well as of the carpet  
8 or the like. When heavily soiled areas are  
9 encountered, it may be desirable to increase the power  
10 of the cleaner to extract the dirt and debris more  
11 effectively. After such area is cleaned, the power  
12 setting can again be reduced.

13 In the past, the selection of the various power  
14 settings of the cleaner has been controlled by the  
15 operator. However, as discussed hereinabove, the  
16 ability of the operator to detect dirt and debris on  
17 many surfaces significantly is limited, such that the  
18 cleaner often is operated at less than optimum power  
19 levels for the areas being cleaned.

20 Efforts have been proposed to assist the operator  
21 in detecting whether dirt and debris is being extracted  
22 from the area being cleaned. Such efforts include  
23 providing a thin diaphragm within an opening in the  
24 wall of the vacuum cleaner airflow passageway,  
25 preferably at a bend in the passageway. The diaphragm  
26 is so constructed and positioned that particles passing  
27 through the airflow passageway impinge against the  
28 diaphragm thereby creating an audible sound. The  
29 operator listens for such audible sound as an  
30 indication that dirt and debris are being removed from  
31 the area. The operator may then continue cleaning the  
32 area until the audible sound ceases, indicating the  
33 area is clean. Similarly, the operator can control the

1 power setting of the cleaner, as heretofore discussed,  
2 in response to the audible sound created by the dirt  
3 and debris impinging against the diaphragm.

4 While the foregoing system may be helpful in  
5 detecting dirt and debris, it is ineffective due to  
6 several inherent shortcomings. Specifically, the  
7 system requires the diaphragm to be exposed directly to  
8 the airflow through the passageway. This requires a  
9 special mounting and/or amplifying assembly resulting  
10 in a more cumbersome, complex and expensive passageway.  
11 Furthermore, such direct exposure significantly  
12 increases the risk that the thin membrane of the  
13 diaphragm may be damaged by heavier or sharp objects  
14 carried into the passageway by the airflow.

15 The prior system also requires the diaphragm to be  
16 positioned near the user, to enable the user to hear  
17 the audible sound over the cleaner and other  
18 environmental noises. Accordingly, such a system may  
19 be usable with canister-type cleaners but not with  
20 conventional upright cleaners. Furthermore while  
21 heavier material, such as sand, may produce a  
22 recognisable sound upon impinging the diaphragm, other  
23 lighter material, such as dust, would be less able to  
24 produce such a sound. Indeed, some material impacting  
25 the diaphragm may generate sound waves outside the  
26 frequency range of the human ear. Accordingly, the  
27 operator remains uncertain whether or not the specific  
28 area has been thoroughly cleaned.

29 Attempts to detect dirt in the airflow using  
30 photoelectric sensors also have proved ineffective. It  
31 is difficult to calibrate the sensitivity of such  
32 sensors accurately to detect heavier sand as well as  
33 fine dust and talc. Furthermore, the sensor must be

1 exposed to the airstream with the attendant risk of  
2 damage to the sensor components. An additional  
3 shortcoming of this system is found in the occlusion of  
4 the sensor from accumulated dirt film after a period of  
5 operation of the cleaner. Once occluded, the sensor  
6 becomes ineffective to detect dirt in the airflow.

7 Despite the attempts to provide a vacuum cleaner.  
8 which enables the operator to determine the cleanliness  
9 of a particular area, none has yet resulted in a  
10 cleaner which provides a reliable dirt indicator easily  
11 identifiable by the operator. Furthermore, no system  
12 has provided a control for the operation of the cleaner  
13 in response to the existence of dirt and debris  
14 encountered in the area being cleaned.

15 It is, therefore, a primary object of the present  
16 invention to provide a vacuum cleaner having a sensor  
17 which reliably indicates the presence or absence of  
18 dirt and debris being removed from an area being  
19 cleaned.

20 According to one aspect of the present invention,  
21 a vacuum cleaner comprises suction means for creating  
22 an airflow for transporting dirt from a surface being  
23 cleaned, duct means for conveying the dirt laden  
24 airflow therethrough, and sensing means responsive to  
25 interaction between the duct means and the dirt flowing  
26 therethrough for producing a first electrical signal  
27 representative of dirt within the airflow.

28 According to another aspect of the present  
29 invention, a method for controlling the operation of a  
30 vacuum cleaner having a motor for creating an airflow  
31 for transporting particulate matter through an air  
32 duct, comprises the steps of generating a first  
33 electrical signal responsive to the presence of

1 particulate matter in the airflow; processing the first  
2 electrical signal; establishing preselected parameters  
3 for the first electrical signal; and generating a  
4 second electrical signal when the first electrical  
5 signal meets the preselected parameters.

6 The invention thus makes possible a vacuum cleaner  
7 having a sensor which is not exposed to the airflow in  
8 the passageway of the cleaner and in which the sensor  
9 may be located remote from the operator while  
10 generating a signal perceivable by the operator.

11 Preferably, the operation of the cleaner is  
12 controlled, at least in part, by the signal generated  
13 by the sensing means.

14 The sensing means may take various forms but  
15 preferably is a piezoelectric sensor arranged to detect  
16 vibrations set up by the passage of dirt through the  
17 duct. These vibrations may be in the form of the sound  
18 of the air in the airflow or mechanical from the impact  
19 of the dirt particles against the interior surfaces of  
20 the duct. Alternatively, the sensing means may sense  
21 electrostatic charge created by movement of the air  
22 through the duct.

23 Preferably, there are processing means to receive  
24 the first electrical signal and to generate a second  
25 electrical signal when the first electrical signal  
26 meets preselected parameters. For example, the  
27 preselected parameters may include the first electrical  
28 signal having a pulse amplitude of at least 24  
29 millivolts and a pulse width of approximately 50  
30 microseconds and may include the first electrical  
31 signal having at least three pulses within an interval  
32 of approximately ten seconds.

33 The invention may be carried into practice in



1 various ways but one vacuum cleaner embodying the  
2 invention will now be described by way of example with  
3 reference to the accompanying drawings, in which:

4 Fig. 1 is a perspective view of the vacuum cleaner  
5 with parts thereof broken away to depict a mounting  
6 location for a dirt sensor;

7 Fig. 2 is an enlarged, fragmentary cross-section  
8 of the air duct of the vacuum cleaner depicted in Fig.  
9 1; and,

10 Fig. 3 is a schematic block-diagram for a circuit  
11 for processing the signal of the sensor employed by the  
12 vacuum cleaner depicted in Fig. 1.

13 The vacuum cleaner 10 shown in Figure 1 is of the  
14 kind known as an upright cleaner and includes a base  
15 11, and an upper housing 12 and handle 13, together  
16 pivotally connected to the base 11. The base 11 houses  
17 a cleaner motor, an intake airflow duct and a nozzle  
18 with an opening beneath the base 11 to engage the  
19 floor. Contained within the upper housing 12 is a  
20 substantially rigid exhaust airflow duct 14 which  
21 connects the exhaust port of the cleaner motor with a  
22 filter bag 15 contained within a cleaner jacket 16.

23 The specific arrangement of the internal  
24 components of the cleaner 10 can be considered, in  
25 greater detail, with reference to Fig. 2.  
26 Specifically, a sensor or transducer 20 is secured to  
27 the air duct 14, and preferably to the outer surface  
28 thereof. The transducer 20 may be one of a variety of  
29 sensors which accurately detect acoustical and/or  
30 mechanical vibrations in the frequency range of  
31 approximately 3 KHz to approximately 20 KHz or higher.  
32 It has been found that an acceptable transducer 20 can  
33 be fabricated from thin-film piezoelectric material,

1 such as polyvinylidene fluoride (PVDF) film, having a  
2 thickness of approximately 20  $\mu\text{m}$ . The PVDF film is  
3 metallized on both sides and electrically poled during  
4 manufacture. A suitable transducer 20 may be  
5 constructed from Pennwalt "KYNAR" Piezo Film, 28  $\mu\text{m}$   
6 thickness, available from Pennwalt Corporation, King of  
7 Prussia, Pennsylvania ("KYNAR" is a trade mark of  
8 Pennwalt Corporation). The planar area of the  
9 transducer 20 will depend upon the specific  
10 application; but a transducer 20 measuring  
11 approximately 0.75 inch (1.9 cm) by 1.375 inches (3.5  
12 cm) has been found to produce acceptable results.

13 The transducer 20 preferably is adhesively mounted  
14 to the air duct 14. While a number of different  
15 adhesives may be usable, it is desired that an adhesive  
16 be selected which will provide a secure mechanical bond  
17 between the transducer 20 and air duct 14.  
18 Additionally, the adhesive bond should not impede the  
19 transmission of acoustical stimuli to the transducer  
20 20, as will be appreciated hereinbelow. For this  
21 purpose, a thin layer of silicone adhesive,  
22 approximately 2 mils (0.05 mm) thick, such as RTV  
23 Silicone Adhesive/Sealant, available from General  
24 Electric Co., Waterford, New York, has proved to be  
25 quite acceptable.

26 The location of the transducer 20 on the air duct  
27 14 will depend upon the specific application and may be  
28 located on the interior or exterior of the air duct 14,  
29 although as discussed hereinabove, the exterior of the  
30 air duct 14 is preferred. The transducer 20 may be  
31 located upstream of the cleaner motor, near the nozzle  
32 inlet or, as described, it may be located downstream of  
33 the motor, near the bag outlet of the air duct 14. In

1 the cleaner being described, the transducer 20 is  
2 mounted on the exterior surface of the air duct 14  
3 approximately at the midpoint of the outside arc of a  
4 90° elbow although other locations may be acceptable.  
5 Such a location, on an air duct 14 having a wall  
6 thickness of between 0.020 and 0.030 inch (0.5 and 0.8  
7 mm), has been found to enable the transducer 20  
8 accurately to detect the presence of dirt and debris  
9 passing through the air duct 14, as will be appreciated  
10 hereinbelow.

11 Located elsewhere within the vacuum cleaner 10 and  
12 preferably in the proximity of the air duct 14 within  
13 the upper housing 12 is a control module 21. In this  
14 example, the control module 21 is mounted adjacent the  
15 handle 13 within the upper housing 12; but, again, the  
16 specific location may vary depending upon the  
17 particular cleaner. The control module 21 is  
18 electrically interconnected with the transducer 20 by  
19 an input lead 22. As will be appreciated hereinbelow,  
20 the control module 21 is suitable for controlling the  
21 operation of the cleaner 10 in response to the signal  
22 received from the transducer 20.

23 An indicator light 23 may be mounted in the upper  
24 wall 24 of the housing 12 and is electrically  
25 interconnected with the control module 21 by leads 25.  
26 The indicator light 23 preferably is a low voltage, low  
27 current draw indicator, such as a light emitting diode  
28 (LED), which is controlled by the module 21 to indicate  
29 the passage of dirt and debris through the air duct 14;  
30 as will be discussed hereinbelow. It should be noted  
31 that the indicator light 23 need not necessarily be an  
32 LED as other visual or audible signalling devices are  
33 likewise contemplated. Furthermore, the indicator

1 light 23, or any other signalling device, may be  
2 omitted completely and, instead, the module 21 may be  
3 used only to control the operation of the cleaner 10,  
4 as will be appreciated hereinbelow.

5 The control module 21, and specifically the  
6 circuit logic thereof, can be more fully appreciated  
7 with reference to Fig. 3. The control module 21 is  
8 represented generally by the broken line and is shown  
9 interconnected with the transducer 20 through the input  
10 lead 22, with the indicator light 23 through the leads  
11 25, and with a cleaner motor 26 through a motor lead  
12 27. As configured, the control module 21 is capable of  
13 activating the indicator light 23 and controlling the  
14 performance of the motor 26 in response to the presence  
15 of dirt and debris in the air duct 14 as sensed by the  
16 transducer 20. It should be appreciated that many  
17 different circuits can be assembled for the control  
18 module 21 by one skilled in the art of electronics.

19 The output signal from the transducer 20 is a low  
20 voltage AC signal. This signal is received and  
21 amplified by a first conventional signal amplifier 30.  
22 A gain adjuster 31 may be interconnected with the first  
23 signal amplifier 30 to provide sensitivity adjustment.  
24 In such manner spurious signals from the transducer 20  
25 can be reduced such that only signals indicative of  
26 dirt and debris in the air duct 14 are processed by  
27 control module 21.

28 The amplified signal of the first amplifier 30 is  
29 received by a second conventional signal amplifier 32.  
30 This re-amplified signal is then introduced to a  
31 typical pulse stretch amplifier 33 which increases the  
32 pulse width of the signal for further processing.  
33 Specifically, the signal from the first amplifier 30

1 may have a pulse width of approximately 50 to 160  
2 microseconds which can then be increased with the pulse  
3 stretch amplifier 33 to a pulse width of approximately  
4 5 to 20 milliseconds.

5 The signal from the pulse stretch amplifier 33 is  
6 received by an integrator/timer 34 suitable to activate  
7 the system in response to recurring signals of  
8 sufficient duration which are indicative of a sustained  
9 presence of dirt in the air duct 14. Thereafter, the  
10 integrator/timer 34 maintains activation of the system  
11 for a preselected time interval following termination  
12 of the signal generated by the sensor 20. This avoids  
13 repetitive activation/deactivation of the system with  
14 each passing signal. The system can be set to activate  
15 when approximately three to five pulses are sensed  
16 within an interval of approximately ten seconds. These  
17 parameters generally are indicative of sustained  
18 concentration of dirt in the airflow through the air  
19 duct 14. The time interval after activation of the  
20 system may vary with the particular applications; but  
21 a range of approximately one to five seconds has been  
22 found to be acceptable with a period of approximately  
23 three seconds being preferred. The time interval may  
24 be variable to the user or, more preferably, it may be  
25 fixed at the time of assembly of the cleaner 10.

26 The output signal from the integrator/timer 34 is  
27 once again amplified by a conventional driver amplifier  
28 35 which amplifies the signal to generate a usable  
29 output signal. Such output signal preferably is  
30 approximately 3.0 to 4.5 volts, D.C., which may then be  
31 used to power the indicator light 23, as heretofore  
32 described. Similarly, the output signal may be  
33 directed to other components to control the operation

1 of the cleaner 10 as will be discussed hereinbelow.

2 The combination of the four amplifiers, 30, 32, 33  
3 and 35, respectively, which define the signal  
4 processor, may be contained on a single integrated  
5 circuit (IC) for ease of manufacturing. One particular  
6 IC which has been found to be quite acceptable is a  
7 National Semiconductor LM324 quad op amplifier,  
8 although it will be appreciated that other IC's, singly  
9 or in combination, as well as individual components  
10 thereof, may be used to achieve the same operation for  
11 control module 21.

12 The aforesaid output signal from the driver  
13 amplifier 35, in addition to, or as an alternative to,  
14 energising the indicator light 23, may be interfaced  
15 with other components to control the operation of the  
16 cleaner 10, as, for example, regulating the speed of  
17 the cleaner motor 26. Specifically, the output signal  
18 may be fed to a conventional switching device such as  
19 an infrared switch 36, or any other suitable device  
20 which preferably permits isolation of the sensor signal  
21 from the motor circuit, as would be well known to the  
22 skilled artisan. A particular infrared switch 36 which  
23 has been found to be acceptable is a Motorola MOC3010  
24 opto coupler.

25 The infrared switch 36 is interconnected to a  
26 power supply 40 adequate for the cleaner motor 26. A  
27 motor controller 41 may be interconnected in series  
28 with the infrared switch 36 to control the speed of the  
29 motor 26. Specifically, the controller 41 may be any  
30 of a number of suitable control circuits known in the  
31 art, such as a conventional, low cost, triac control  
32 circuit suitable to switch the motor 26 between low  
33 speed and high speed operation. Accordingly, when

1 interconnected with the infrared switch 36, the motor  
2 controller 41 will switch the operating speed of the  
3 motor 26 in response to the presence or absence of an  
4 output signal from the driver amplifier 35 which, as  
5 indicated hereinabove, is directly related to the  
6 sustained presence of dirt and debris flowing through  
7 the air duct 14 of the cleaner 10.

8 The foregoing description may be more fully  
9 understood and appreciated by considering the operation  
10 of the vacuum cleaner 10. Specifically, the motor  
11 controller 41 is able to regulate the power input to  
12 the motor 26 to operate normally at approximately 60  
13 percent of full power. It should be appreciated that  
14 this low power setting is determined in relation to the  
15 nominal power required to allow the cleaner 10 to lift  
16 dirt effectively from the surface being cleaned; and  
17 that such a setting will vary for different types of  
18 cleaners.

19 As dirt is drawn into the unit and discharged  
20 through the air duct 14, its presence is detected by  
21 the transducer 20. Tests have revealed that the  
22 transducer 20 is capable of detecting dirt  
23 acoustically, by detecting the sound of the dirt in the  
24 airflow; mechanically, by detecting the vibrations from  
25 the impact of the dirt particles against the interior  
26 surfaces of the air duct 14; and electrostatically, by  
27 sensing the electrostatic charge created by the  
28 movement of the dirt through the air duct 14. In  
29 response to the presence of the dirt, the transducer 20  
30 generates an AC signal of approximately 70 to 120  
31 millivolts, which has been found to be sufficient to  
32 trigger the control module 21.

33 When the signal from the transducer 20 meets or

1 exceeds the aforesaid parameters of three to five  
2 pulses within a ten second interval, the control module  
3 21 increases the power input to the motor 26 to  
4 increase the cleaning effectiveness of the cleaner 10.

5 The motor 26 will continue operating at the  
6 elevated power setting as long as dirt and debris in  
7 the air duct 14 are sufficient to generate signals  
8 within the aforesaid parameters. Then module 21 will  
9 maintain the increased power setting of the motor 26  
10 for approximately three seconds following reduction of  
11 dirt concentration in the air duct 14, as discussed  
12 hereinabove. Following this, the control module 21  
13 will switch to the lower power setting for the motor  
14 26. The system will remain in this condition until  
15 dirt of sufficient concentration again is sensed in the  
16 air duct 14.

17 It has been found that the sensitivity of the  
18 system may reasonably be such that the control module  
19 21 will trigger at low frequency signals, such as  
20 signals in the 2-3 KHz range. However, these signals  
21 may be associated with line voltage interference, motor  
22 vibrations and the turbulent flow of air through the  
23 air duct 14. Typical filters may be employed to  
24 eliminate such nuisance signals thereby avoiding false  
25 triggering of the module 21. Furthermore, the  
26 amplitude sensitivity of the system may be adjusted  
27 using the gain adjuster 31, as discussed hereinabove to  
28 allow activation of the system at signal amplitudes of  
29 approximately 70 millivolts or less. In this manner,  
30 the module 21 may be suitably adjusted to trigger only  
31 on filtered signals generated by the transducer 20 as a  
32 result of dirt of preselected concentration flowing  
33 through the air duct 14.



1 Tests have revealed that granular dirt, such as  
2 sand, may produce signals having a pulse amplitude of  
3 approximately 80 millivolts, with a pulse width of 50  
4 microseconds, which is quite sufficient to trigger the  
5 module 21. However, if desired, the sensitivity  
6 parameters of the system may be increased to the extent  
7 that signals having a pulse amplitude of approximately  
8 24 millivolts, and a pulse width of approximately 50  
9 microseconds, will trigger the module 21. This would  
10 generally be sufficient to trigger the module 21 in the  
11 presence of fine dirt and dust particles. However, at  
12 this sensitivity level adequate signal filtering means,  
13 as discussed above, may be necessary to eliminate false  
14 triggering of the control module 21 by low frequency  
15 signals caused by extraneous sources in the cleaner, as  
16 may be known to one skilled in the art.

17 While the foregoing is a description of one  
18 embodiment of the invention, by no means does it  
19 constitute the exclusive embodiment. For example, the  
20 invention may be incorporated into other types of  
21 vacuum cleaners, such as canister cleaners.  
22 Furthermore, the sensor may be positioned at other  
23 locations throughout the dirt path to sense the flow of  
24 dirt; and more than one sensor may be employed, or more  
25 than one type of sensor, to extend the sensitivity  
26 range for sensing dirt. Also, alternative electronics  
27 may be employed to process the signal from the sensor  
28 to produce a usable output signal. Then, too, means  
29 may be provided in the form of a switch, for example,  
30 to override or disconnect the system, and allow the  
31 cleaner to function in a conventional manner.

32 It should be appreciated that the present  
33 invention provides an effective indication of cleaner

1 operation and/or closed-loop control for the motor 26  
2 of the cleaner 10. Such a system allows for highly  
3 efficient cleaner operation and efficient utilisation  
4 of operator efforts in vacuuming carpets or other  
5 surfaces.

6 The overall durability of the cleaner 10 is  
7 improved due in part to the fact that the cleaner 10 is  
8 operated more often at low power with only intermittent  
9 periods of high speed operation. The life of the  
10 cleaner motor, bearings, brushes and other components  
11 may be increased significantly as a result of the low  
12 power operation. These critical components can be  
13 designed to less demanding standards, resulting in less  
14 expensive assemblies. Furthermore, the carpet itself  
15 is exposed to less wear because of the generally lower  
16 operating speed of the cleaner 10.

17 It should also be appreciated that a cleaner  
18 embodying the present invention greatly assists the  
19 operator in cleaning. By means of a perceptible  
20 indicator, such as a light, and/or change in operation  
21 of the cleaner motor, the operator can identify when a  
22 dirty area is encountered. The operator can then  
23 continue cleaning in the identified area until the  
24 cleaner indicates that dirt is no longer being removed  
25 therefrom. Thereafter, the operator may proceed to an  
26 area that has not been cleaned without expending undue  
27 time. Additionally, with the cleaner generally  
28 operating at a lower power level, the operator is less  
29 exposed to the noise and vibration generated by the  
30 cleaner at higher operating levels, thus reducing the  
31 fatigue of the operator.

32 Although the foregoing has considered a cleaner  
33 operating normally at a lower speed, it is likewise

1 contemplated for the cleaner normally to operate at a  
2 higher speed with intermittent periods of lower speeds.  
3 In this fashion, the operator may clean a given area  
4 quickly at high speed operation but, when sensor 20  
5 detects dirt, the cleaner may switch to a lower speed  
6 so as to avoid damaging internal components of the  
7 cleaner by heavy particles of dirt and debris. When  
8 such heavy concentration of dirt has been reduced, the  
9 cleaner, again, may return to high speed operation.

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1     Claims:

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3     1.    A vacuum cleaner comprising suction means for  
4     creating an airflow for transporting dirt from a  
5     surface being cleaned, duct means for conveying the  
6     dirt laden airflow therethrough, and sensing means  
7     responsive to interaction between the duct means and  
8     the dirt flowing therethrough for producing a first  
9     electrical signal representative of dirt within the  
10    airflow.

11

12    2.    A vacuum cleaner as claimed in claim 1 which  
13    includes processing means to receive the first  
14    electrical signal and to generate a second electrical  
15    signal when the first electrical signal meets  
16    preselected parameters.

17

18    3.    A vacuum cleaner as claimed in claim 2 which  
19    includes controller means to receive the second  
20    electrical signal and to regulate the suction means in  
21    response thereto.

22

23    4.    A vacuum cleaner as claimed in claim 3 in which  
24    the suction means is an electric motor and the  
25    controller means regulates the operation thereof.

26

27    5.    A vacuum cleaner as claimed in claim 2 or claim 3  
28    or claim 4 in which the preselected parameters include  
29    the first electrical signal having a pulse amplitude of  
30    at least 24 millivolts and a pulse width of  
31    approximately 50 microseconds.

32

33

1 6. A vacuum cleaner as claimed in claim 5 in which  
2 the preselected parameters include the first electrical  
3 signal having at least three pulses within an interval  
4 of approximately ten seconds.

5  
6 7. A vacuum cleaner as claimed in any of claims 2 to  
7 6 in which the processing means includes timer means to  
8 maintain generation of the second electrical signal for  
9 a preselected period of time following termination of  
10 the first electrical signal to meet the preselected  
11 parameters.

12  
13 8. A vacuum cleaner as claimed in any of claims 2 to  
14 7 which includes indicating means responsive to the  
15 second electrical signal.

16  
17 9. A vacuum cleaner as claimed in claim 8 in which  
18 the indicating means is an indicator lamp.

19  
20 10. A vacuum cleaner as claimed in any preceding claim  
21 in which the sensing means is affixed to the duct means  
22 and is physically displaced from the airflow.

23  
24 11. A vacuum cleaner as claimed in any preceding claim  
25 in which the sensing means is an acoustical transducer.

26  
27 12. A vacuum cleaner as claimed in any preceding claim  
28 in which the sensing means is a piezoelectric  
29 transducer.

30  
31 13. A vacuum cleaner constructed and arranged to  
32 operate substantially as described herein with  
33 reference to the accompanying drawings.

- 1 14. A method for controlling the operation of a vacuum  
2 cleaner having a motor for creating an airflow for  
3 transporting particulate matter through an air duct,  
4 comprising the steps of: generating a first electrical  
5 signal responsive to the presence of particulate matter  
6 in the airflow; processing the first electrical signal;  
7 establishing preselected parameters for the first  
8 electrical signal; and generating a second electrical  
9 signal when the first electrical signal meets the  
10 preselected parameters.  
11
- 12 15. A method as claimed in claim 14 which includes the  
13 step of generating a user identifiable signal in  
14 response to the second electrical signal.  
15
- 16 16. A method as claimed in claim 15 in which the user  
17 identifiable signal is provided by an indicator lamp.  
18
- 19 17. A method as claimed in claim 14 or claim 15 or  
20 claim 16 which includes the step of regulating the  
21 airflow through the air duct in response to the second  
22 electrical signal.  
23
- 24 18. A method as claimed in claim 17 in which the step  
25 of regulating the airflow includes controlling the  
26 operation of the motor.  
27
- 28 19. A method as claimed in any of claims 14 to 18 in  
29 which the step of generating a first electrical signal  
30 includes affixing a transducer to the air duct at a  
31 location physically displaced from the airflow, and  
32 exciting the transducer by passing particulate matter  
33 through the air duct.

1 20. A method as claimed in any of claims 14 to 19  
2 which includes the step of maintaining generation of  
3 the second electrical signal for a preselected period  
4 of time following termination of the first electrical  
5 signal to meet preselected parameters.

6

7 21. A method of controlling the operation of a vacuum  
8 cleaner substantially as described herein with  
9 reference to the accompanying drawings.

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